The following article started out as a guest editorial, another in the set of early career guest editorials. By the Nth iteration it had grown to seven thousand words. Though it has outgrown its original niche, it has not outgrown its original purpose. I hope that you'll agree with me, that it's also a great read. Richard Price, Editor

Uncle Jesse and the seven "early career" ladies of the night[1]

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ABBREVIATIONS USED

AIS	Anneila Isabel Cassells Sargent
AVP	Arsine Victoria Avakian Peterson
CHPG	Cecilia Helena Payne Gaposchkin
DW	Donna Etta Weistrop
JGC	Judith Gamora Cohen
JLG	Jesse L. Greenstein
MHH	Marjorie Hall Harrison
SEK	Susan Elizabeth Zimmet Kayser
SWK	Susan Elizabeth Werner Kieffer
VT	Virginia Louise Trimble

Jesse Leonard Greenstein (1909–2002) was apparently a very hard sell when it came to women in astronomy. Early in his autobiography,[2] he wrote of "Miss Payne, a person of wide culture and astronomical knowledge. The obvious discrimination against her as a woman scientist, worthy of normal academic recognition, exacerbated the stressful life she led. She was unhappy, emotional,[3] in a rivalry with Menzel and Plaskett." She (a.k.a. Cecilia Helena Payne, later Gaposchkin) is the only woman with an explicit mention in that memoir, and Greenstein's impression of her left him uncertain whether women belonged in astronomy. In addition, some of us remember him as saying there was no use in educating women through to a Ph.D. because they only get married and quit.[4–7]

Nonetheless, it was on JLG's watch as head of Caltech astronomy[8] that the seven of us arrived at the graduate program, in a tight temporal cluster (see the short bios below), apparently the first women to do so, with no others receiving Caltech advanced astronomy degrees until 1990.

This is part of our story. We are telling it here collectively for the first time[9] and perhaps at the last opportunity since we are all nearly the same age, and it is not a particularly youthful one. All of us, at some time or other, and if only briefly, occupied the room at the back, to the right, in Robinson Library.[10] But we have never all been together at once nor does it now seem likely that we will ever be. Nevertheless, the process of compiling this brief collective autobiography has given us the opportunity to share recent events in our lives as well as some of the old stories about being young women at Caltech, half a century ago, and so once again to feel for a moment like "early career astronomers."

We differed systematically both from those who came before and from those who have come after. We all married, unlike many earlier female astronomers. Though we have not achieved the replacement rate in biological children, we have slightly exceeded it in scientific progeny. None of us were among the first 15, pre-1978, recipients of the Annie J. Cannon Prize (the women-only award of the American Astronomical Society). Several of us worked directly with Greenstein, and we have all taught physics, astronomy, geosciences, or some closely related field.

Teaching physics might have been a sore point; at least one of us was told to get an MS degree that included physics because the only jobs available would probably be as the token astronomer in a small, four-year physics department, perhaps at a women's college. As it turned out, as we emerged from our California chrysalises, academic and research astronomy was booming[11] and only one of us (VT) spent her first post-Ph.D. year as the sole astronomer in the small physics department of a four-year women's college.

One thing we had in common with earlier generations was a disproportionate fraction of us with first degrees from the "seven sisters," private, high-prestige, four-year colleges for women in the American northeast (two Cliffies and a Wellesley girl). The first 12 recipients of the Annie J. Cannon Prize of the AAS, Cannon herself, and three other

contemporary women with AAS recognition of various sorts provide a sample of 15 first degrees including three from Radcliffe, two from Swarthmore, and one each from Wellesley, Vassar, Smith, Barnard, Mount Holyoke, and Goucher. Swarthmore and Goucher were similarly private, four-year, liberal arts colleges, Goucher was for women, while Swarthmore was co-ed (and one of the first American institutions to make that claim). All of the others came from overseas (Cambridge, Copenhagen, London, and Kiel). If you have taken off your shoes to count, one apparently earned a Ph.D. without a preceding B-anything.[12]

A very obvious difference between us and later cohorts (and some contemporaries at other institutions) is that we applied to an educational establishment whose catalog said "women are admitted only under exceptional circumstances." In fact, two of us (SEK, AVP) had husbands also applying to Caltech (one in physics, one in astronomy); one (SWK) came with a faculty member just hired by Caltech, who had been her advisor at another more broad-minded (sorry) university; one (AIS) was married to a Caltech faculty member when she applied; and three (VT, JGC, DW) came with funding promised for at least the first year, not to be drawn from Caltech's (bulging) pockets. One of the barriers that had fallen just ahead of us was the availability of National Science Foundation and NASA Graduate Fellowships for women.

Another tottering wall was the one that had excluded women from the two observatories available to Caltech men: Mt. Wilson and Palomar Mountain, with their 100″ Hooker and 60″ (Mt. Wilson) and 200″ Hale and 48″ Oschin Schmidt (Palomar) telescopes. Under director Ira S. Bowen, extragalactic astronomer E. Margaret Burbidge (whose degrees came from London) used telescope time officially assigned to her husband, Geoffrey. Horace Welcome Babcock, appointed director in 1964, permitted gradual changes. Visitor Vera Cooper Rubin[13] received time in her own name on the Palomar 200″. Postdoc Anne Merchant Boesgaard (1966–1967) broke the gender barrier at Mt. Wilson. And six of us, their beneficiaries, spent at least a bit of time at one or both of those two mountaintop observatories, with their housing facilities called monasteries.

The changes did not occur without incident, and many of the stories we have exchanged while preparing this verbal morsel have dealt with who sat at the monastery dinner table or carried the lunch basket. Could you sleep on the mountain or have to drive back down before you could have a shower and a bed? Which of the official male observers were willing to shepherd a gal or two on her compulsory "watch how astronomy is done" visit to one site or the other? J. Beverly Oke and Guido Munch, yes; Greenstein no, though he held several speed records for getting between Caltech and the observatory sites. Before we forget, there was rapid evolution. At least two of us remember our first observing run at Palomar, with the entire upper floor of the monastery roped off for the one woman. Next run, it was just a two-bedroom plus bathroom upper floor unit occupied solo. On the third, while still entitled to a whole unit, VT found herself downstairs with the men.

The pioneering situation was slightly different at Mt. Wilson, where, rumor has it, the male observers did not want to have to get dressed to use the one-holer facilities. There existed something called the Kapteyn Cottage because Jacobus Kapteyn and his wife Catharina stayed there when he was a visiting astronomer from the Netherlands in the summers before World War I. According to JGC, it had running cold water, which could be heated on a stove, and no other heat source. DW reports that even the stove defeated her. Improvements occurred gradually, and the building was eventually taken over for use by the Georgia State astronomers who operate an optical interferometer on the mountain. Other minor anomalies lingered. Women, under California law in those days, were limited as to hours of night work they could perform (a relic of an international agreement that survived in the Treaty of Versailles) and were limited to jobs that did not require lifting more than 40 pounds. The 48″ plateholder, unfortunately… Stories about the night assistants of the period portray them all as kind, but perhaps particularly so to us.

Other then-and-now differences were not gender dependent, for instance, the qualifying exam. It was, for all in astronomy, a multi-hour oral, with multiple faculty members arrayed like a firing squad opposite one defenseless graduate student. VT remembers five, but perhaps she was seeing double? She also failed the first time around (which has been useful in counseling graduate students ever after), though none of the others did. The questions were not just from course work or even primarily from course work. Rather, the student was supposed to have mastered topics covered in Department colloquia (a one-credit course) and a broad range of topics at the *Scientific American* level. In contrast, the thesis exam was fun. Unless something had gone wrong, the student knew more about the subject than anyone else in the room, which again held about five faculty members, including one from Physics.

Some of us hurried through the whole thing; others not so much (see the bio's following the text). But we all took more formal classes than is now the custom. Caltech course credits reflected the total number of hours per week you were supposed to spend, both in lectures (etc.) and on homework. Most of the first and second year courses counted as 9 credits, and a typical first year curriculum had, for each of the three terms, three kinds of physics, two kinds of astronomy, and philosophy or something else needed to collect an MS along the way. Second year might be two years of physics (at least one with a course number larger than 200[14]), three kinds of astronomy, and, at some point, a language had to be tucked in for anyone who didn't arrive reading two at the level required to stumble through a couple of pages of text in some subfield of astronomy. These were rather old fashioned, even for the time: building a refractor or finding the zenith in French; measuring radial geschwindigkeit of binary stars in German. Prof. Oke said later that he had been asked more than once for more up-to-date texts but had never done anything about it. The alternative was a formal course, of up to a year, either at Caltech or Pasadena City College, droppable when one passed the reading exam. The Caltech text included items in not only psychology, biology, chemistry, physics, and industrial practices, as they were in about 1950 but also "Das Attentat zu Sarajevo" (lesson 28 of 30, and the first appearance of the word for wife, which probably goes to show something or other).[15]

Now about money. Earlier generations were very much aware that women astronomers were generally paid less than men.[3,16] Assorted statistical studies indicate that this is still true at many universities, industrial organizations, and research facilities. But the government agencies (NSF and NASA), private foundations (e.g., Woodrow Wilson), and even Caltech itself gave us the same stipends as the male

students. How much? About $200 a month in all cases, rising slightly for the 3rd and 4th years. That's about $1.25 per hour for a "normal" 40-hour work week (just equal to the federal minimum wage at the time), but more like 75¢/hour for the day, swing, and graveyard shifts we actually worked, and again about the same for all. The difference came in what it had to cover. Unmarried male students could live in dormitories (called "houses" there) at $65/month for room and board. Couples with two stipends might manage a typical one-bedroom apartment, renting for $110/month, though there were some landlords who refused 22 year olds as "not adult." Unattached females faced a steeper challenge, as, of course, did our 20 or so women classmates in other departments, some of whom were married, but certainly not all. Single rooms or studio apartments were to be had for about $75–85/month, but this still left food to be provided.

JGC persuaded the Caltech administration to let her and three or four other women (not from astronomy) operate a house Caltech owned near campus as a co-op. Refrigerator space quickly became as precious as office space on campus, and she moved to a small private unit after a year. What about other expenses? Gas for heating and cooking varied seasonally from $4.25 to $6.85 per month; electricity for the refrigerator, lighting, perhaps a radio, and television (no home computers in those days!) $3–5/month (billed bi-monthly); the base rate for a phone, if you didn't actually use it, was $4.15; and the LA Times was $3 a month.[17] Gasoline came in at 3–4 gallons per dollar, if you could manage a car, and it could be insured for $48/year, with maintenance running perhaps twice that, except for the $345 rebuilt motor experienced by one couple.[18]

Social events included Shakey's pizza on Friday evenings, where the "fundamental monetary unit" was the pitcher of beer at Shakey's ($1.25, $1.35 for premium). There were occasional hobbit parties, with the more enthusiastic invitees dressed as favorite characters.[19] Passing of the qualifying exam or successful defense of one's thesis was marked by the celebrant giving an evening party for the full complement of graduate students plus any faculty who chose to come. (Richard Feynman only very rarely, but that is part of a different story.) A favorite fluid was Jovian Joy Juice, supposedly the invention of a student of a slightly earlier period, comprising sizable quantities of gin and rum, plus grapefruit and pineapple juices and cold tea, which[20] tended to keep the imbiber from noticing the first two ingredients until shortly after the nick of time.

We were permitted to join the faculty club (the Athenaeum) at a reduced monthly rate and eat lunches there from time to time, sometimes as part of "Take an astronomer to lunch" day, when the students collectively paid for a faculty or observatory staff member or visiting pundit. A couple of us were in years where weekly attendance was compulsory, with a bill running from $2.50 to $4.25. The dress code, jackets and ties for men and dresses or suits for women, was one item harder on the guys, a subset of whom worried visitors by wandering around in zori or even barefoot, wearing shorts in the California winter. Names were more challenging for women than for men.[21]

Being a graduate student naturally imposed significant other costs. Not paper and pencils; those we snitched from various cupboards, and pocket calculators arrived only in 1972. Textbooks were the heaviest burden. Goldstein's *Classical Mechanics*,[22] Robert Leighton's *Principles of Modern Physics*,[23] and quantum mechanics by Dicke and Wittke[24] ran to $11.50, $12.50, and $9.75, respectively. The German text was only $4.50, but the dictionary was $8.50. Notice that such books cost about the same fraction of a month's rent as a serious graduate text in physics does today. Curiously, none of us seems to remember the cost of the traumatic, first edition of Jackson's *Electrodynamics*[25–27] Reviewers at the time drew attention to the mathematical difficulty, the omissions of intermediate steps in derivations (also a hallmark of the Landau and Lifshitz volumes), the relegation of important physical principles to homework exercises, and other difficulties. We are all too old to have encountered the later, 1975 and 1997 Jackson editions, supposedly less harrowing, except perhaps to teach from.[28] But to cool off at Caltech, we could swim in an Olympic-size pool (10 laps = 1/4 mile) for only $7 or $8 per year and climb around nearby hills and dales for free.

At less self-assured universities, in graduate courses, "A is average and B is bad." But the Caltech requirement for successful completion of graduate courses was and remained up to 2004 a C average. This explains, coming only 50 years after the fact, why those of us pulling through E&M with "ladies' C's" were never scolded for it.

Completing a thesis meant getting it typed, error-free, on special paper, generally by a professional, and providing copies for each committee member (at least three weeks before the scheduled defense), one for University Microfilms and perhaps one for parents. The total was variously $100–150. But junior membership in the American Astronomical Society was only $10/year.

First jobs were not exactly applied for in those days, by either men or women as newly minted Ph.D.'s. Rather, one's advisor recommended one to his colleagues who were looking for a postdoc, a faculty sabbatical replacement, or a data processor. Applying for (supposedly) gender-neutral fellowships was another possibility. See the short bio's below for what we all actually did. But VT at least is of the opinion that the most important development in providing equal opportunities for women in astronomy has been the job register maintained by the American Astronomical Society, which now also includes many positions in other countries. This enables the new Ph.D. or other career-hunter to find out what is available and to decide for herself what is worth applying for and how to do it.

But we were all young, chronologically probably somewhat younger than the average physics or astronomy graduate student today, and socially, we suspect, considerably younger. And we had rational expectations of careers that would keep us in science one way or another, with incomes that would no longer place us below President Lyndon Johnson's poverty line, a line which, when we first heard about it at one of the group celebrations, caused general laughter at the realization that we were all below it, but wouldn't always be. That we emerged near the end of the post-Sputnik enthusiasm for space and related sciences probably made our quests less strenuous than those faced by new astronomy, etc., Ph.D.'s today. A first-year postdoc then might come with a salary around $6000, and a teaching position could be up to $9,500 for a nine-month contract. Percentagewise, these were the largest raises we would ever get and, again as a ratio, probably exceed the current increments associated with completing a Ph.D. But it is still worth doing, we all agree!

ACKNOWLEDGMENTS

The authors remain, of course, deeply grateful, though this side idolatry,[29] to our advisors, who were undertaking tasks new to them. They were Peter Goldreich, Guido Munch, Maarten Schmidt, the late Halton C. (Chip) Arp, Armin Deutsch, Jesse Greenstein, Robert P. Kraft, J. Beverly Oke, Eugene Shoemaker, and Harold Zirin (who attempted to make up for the loss of SWK to geosciences by coaching VT through the second round of the qualifying exam that she had failed the first time). An extra "thank you" goes to Munch, whose oral history with the American Institute of Physics provided the names of the three University of Chicago women astronomy Ph.D. degrees who did get married and, at least by JLG's standards, dropped out.

- Susan Elizabeth Zimmet Kayser (SEK in the text)
  - *First degree:* 1960, Radcliffe College, AB physics
  - *Caltech degree:* 1965, Ph.D. Astronomy
  - *Married:* 1961, Boris J. Keyser (Ph.D. Physics, Caltech 1961); *Children:* none
  - *First Caltech project:* Assistant to J. B. Oke
  - *Ph.D. dissertation topic and advisor:* Photometry of NGC 6822;[30] H. C. (Chip) Arp and J. L. Greenstein
  - *First jobs:* postdoc Lawrence Livermore Lab 1966; postdoc Yeshiva University 1966–1968; research associate SUNY Stony Brook 1968–1969; U. of Chicago School of Pharmacy teaching physics 1969–1970; research associate and physics teaching U. Chicago at Chicago Circle 1970–1971; Chicago State University teaching elementary physics 1971–1974; Computer Sciences Corporation at Goddard Space Flight Center data analysis 1974–1995
  - *Teaching:* Physics many places; astronomy at Benedictine University after 2001
  - *Signature accomplishment:* First woman to complete a Caltech astronomy Ph.D. and, *ad astra per aspera*, not drop out of the field, broadly interpreted
- Arsine Victoria Avakian Peterson (AVP in the text)
  - *First degree:* 1961, MIT, ScB Physics
  - *Caltech degree:* MS 1966, Ph.D. 1970, both astronomy
  - *Married:* 1963 Bruce A. Peterson (Ph.D. astronomy, 1969 Caltech); *Children:* two
  - *First Caltech paper or second year research project and advisor:* Molecules in stellar spectra, J. L. Greenstein
  - *Ph.D. Dissertation topic and advisor:* O type subdwarfs, G. Munch
  - *First jobs:* Australian National University and Mt. Stromlo Observatory, postdoc, 1969–1971, then teaching faculty from 1971
  - *Teaching:* ANU astronomy, then computer sciences, 1971–2006
  - *Signature accomplishment:* Ice climbing in New Zealand to the top of Mt; Cook, a/k/a Aroki, New Zealand's deadliest mountain
- Virginia Louise Trimble (VT in the text)
  - *First degree:* 1964 UCLA, BA Astronomy & Physics
  - *Caltech degrees:* MS 1965, Ph.D. 1968, both astronomy
  - *Married:* Joseph Weber (Ph.D. Physics, Catholic Univ. of America 1951, d. 2000); *Children:* none (four stepsons)
  - *Second year research project or first Caltech paper and advisor:* The Einstein redshift in white dwarfs;[31] J. L. Greenstein.
  - *Ph.D. Dissertation topic and advisor:* Filaments in the Crab Nebula.[32] Munch
  - *First jobs:* Visiting asst. prof. Smith College 1968–1969; Postdoc Inst. of Theoretical Astronomy, Cambridge UK, NATO & fellow Newnham College 1969–70m IOTA & fellow Girton College, 1970–1971
  - *Teaching:* Physics & Astronomy, Smith 1968–1969; U. California Irvine 1971–present; U. Maryland 1973–2003
  - *Signature accomplishment:* only person to have been the President of two different Divisions of the International Astronomical Union; Drta. h.c. U. Valencia, Spain
- Susan Elizabeth Werner Kieffer (SWK in the text)[33]
  - *First degree:* 1964, Allegheny College, BA Physics and Mathematics; U. Colorado 1964–1965
  - *Caltech degrees*: MS 1967 Geoscience; Ph.D. 1971 Planetary Sciences. Married
  - *Second year research project or first Caltech paper & adviser:* Sunspot group of 1962;[34] Harold Zirin.
    Ph.D. dissertation topic and advisor: Coconino Sandstones at Meteor Crater;[35] Eugene Shoemaker
  - *First jobs:* Prof. of Geology UCLA 1973–1978; U.S. Geological Service 1979–1990 (simultaneously Regents Prof. of Geology Arizona State U.), U. British Columbia (Head of Geological Sciences Dept. 1993–1998), Toronto, to private sector to U. Illinois
  - *Teaching:* UCLA, ASU, UBC, U. Toronto, and U. Illinois
  - *Signature accomplishment:* Elected to U.S. National Academy of Sciences; MacArthur fellow 1995.
- Anneila Isabel Cassells Sargent (AIS in the text)
  - *First degree:* 1963, Univ. of Edinburgh B. Sc. Hons. Physics (to UCSD to CIT)
  - *Caltech degree:* MS 1967, Ph.D. 1978, both Astronomy
  - *Married:* 1964, Wallace L.W. Sargent (Ph.D. Physics, Univ. of Manchester 1959, d. 2012); *Children:* two daughters
  - *Second year research project or first Caltech paper and advisor:* Faint blue stars in the halo;[36] J. L. Greenstein
  - *Ph.D. Dissertation topic and advisor:* Molecular clouds and star formation;[37] Peter Goldreich
  - *First jobs:* research fellow, professional staff, Caltech
  - *Teaching:* Caltech astronomy
  - *Signature accomplishment:* Start-up director of CARMA, D.Sc. U. Edinburgh, Caltech distinguished alumna, and more
- Donna Etta Weistrop (DW in the text)
  - *First degree:* 1965 Wellesley College, BA Astronomy
  - *Caltech degree:* Ph.D. 1971, Astronomy
  - *Married:* 1979, David B. Shaffer (Ph.D. Astronomy, Caltech 1974)
  - *Second year research projects or first Caltech papers and advisor:* Hα in late-type stars;[38] Robert Kraft
  - *Ph.D. dissertation topic and advisor:* Disk luminosity function;[39] local population two density;[40] Maarten Schmidt
  - *First jobs:* Staff member and visiting lecturer, Tel Aviv University and Wise Observatory, 1971–1973; Postdoc Ohio State University 1973–1974; to Kitt Peak (KPNO), U. Arizona, Goddard Space Flight Center, Applied Research Corporation, to U. Nevada Las Vegas 1990
  - *Teaching:* Tel Aviv U. 1971–1973 Physics; UNLV Astronomy 1990–2005
  - *Signature accomplishment:* First recipient of Donna Weistrop career achievement award from the College of Science and Mathematics UNLV

- Judith Gamora Cohen (JGC in the text)
  - *First degree:* 1967 Radcliffe, BA Astronomy
  - *Caltech degree:* Ph.D. 1971, Astronomy
  - *Married:* 1974, Gaston Araya; *Children:* None
  - Second year research project or first Caltech paper and advisor: The spectrum of a^2 CVn;[41] Armin Deutsch and J. L. Greenstein
  - *Ph.D. dissertation and adviser:* Lithium in F and G stars;[42] Guido Much
  - *First jobs:* Miller Fellowship, UC Berkeley 1971–1974, assistant astronomer KPNO 1974–1978, Caltech professorial sequence 1979–present
  - *Teaching:* astronomy at Caltech, named professorship
  - *Signature accomplishment:* First woman on the Caltech Astronomy faculty

[1]No, no! Those are Ladies of the Evening (as in the song from Rogers and Hart's *Boys from Syracuse*). Ladies of the Night are women astronomers.

[2]Jesse L. Greenstein, "An astronomical life," in *Annual Reviews of Astronomy and Astrophysics*, edited by Geoffrey Burbidge (Annual Reviews, 1984), Vol. 22, pp. 1–34. His degrees were from Harvard, with a brief intermission to help in the family business during the depression. In addition to a truly enormous number of other advisory panels and such, JLG chaired the second of the astronomy "decadal" surveys and apparently made so many enemies in that process that he became the first person ever to be defeated for the office of President of the American Astronomical Society, losing in 1973 to Robert Kraft, a former member of the Mount Wilson-Palomar staff, who had decamped to Lick Observatory, while many of us were at Caltech. Greenstein never felt quite the same way about the astronomical community afterwards and somewhat changed the focus of his non-research activities. He and his wife, Naomi, collected Chinese paintings and drawings, and, when they had to downsize to move to a care center, he offered one of them to VT—for $3000. Soon after the Greensteins arrived at their new home, Jesse was elected president of the tenants' association.

[3]This simply is not the Cecilia Helena Payne Gaposchkin whom some of us knew in later years. For her own view, see *Cecilia Payne-Gaposchkin: An Autobiography and Other Recollections*, 2nd ed., edited by Katherine Haramundanis (Cambridge U. P., I996). This volume includes an autobiography by CHPG called "The Dyer's Hand" and forwards by historian of science Peggy Kidwell and by JLG and VT. CHPG earned a first degree at Cambridge University (Newnham College) and came to Harvard on a modest fellowship to work with the director of the observatory Harlow Shapley. Her 1925 Ph.D. dissertation (juggled gingerly between Harvard and Radcliffe) was the first in astronomy from those organizations. Scientifically, the most important thing to know about her is that her thesis established beyond doubt—as seen with 20-20 hindsight—that nearly all stars have the same chemical composition (accepted immediately) and that hydrogen and helium overwhelm the other elements (not fully accepted until confirmed in 1929 by Henry Norris Russell, who had initially been her harshest critic).

[4]This seemed initially a little odd! "Miss Payne" certainly married (Sergei Illarionovich Gaposchkin) and bore three children, but certainly never left astronomy. Women who overlapped JLG's time at Yerkes Observatory and the University of Chicago included Anne Barbara Underhill (1920–2013) and Nancy Grace Roman 1925–2018, who neither married and neither left astronomy. As for Greenstein's first female postdoc at Caltech, Anne Merchant added Boesgaard to her name the same year (1966) that she received her Ph.D. at the University of California, Berkeley, and came to Caltech, but far from quitting, she has just been named the 2019 Russell Lecturer of the American Astronomical Society (its highest honor) for her work on the abundance of lithium in stars, among other achievements. Deeper digging found, also overlapping JLG's Chicago years (1937–1947), four more women: (1) Esther Marley Conwell (1948 Ph.D. with Chandrasekhar, though officially a physics student). Since she in due course received a National Medal of Science, she cannot be counted as a drop-out, though her later work was in chemistry. (2) Marjorie Hall Harrison (Ph.D. 1947), who published her dissertation work and a couple of other Yerkes based papers, married (the ADS site has her as Hall Harrison), had children, and, for the rest of her career, taught astronomy at Sam Houston State University in Huntsville, Texas, dying at 67 of lung cancer (maybe half a point for Jesse). (3) Margaret Kiess Krogdahl[4–7] (Ph.D. 1944), who married Wasley Krogdahl, had three children and accompanied her husband to Lexington, Kentucky, where he was professor of astronomy for many years. (4) Merle Eleanor Tuberg (Ph.D. 1946) was appointed to a postdoctoral position in Cambridge, UK, where she met and married astrophysicist Thomas Gold (divorced 1971, after the birth of three daughters), and it was said in her obituary, after she had chosen family over science. So, depending on how you feel about Sam Houston State U (whose current faculty members were enormously helpful in tracking down Marjorie Hall Harrison's details), either two or three dropouts post Ph.D.[6] Incidentally, all the Chicago women, except Underhill (who worked with W. W. Morgan) were students of Chandrasekhar (Nobel in physics 1983). We who came under Munch at Caltech are Chandra's "doctor granddaughters." He actually read at least one of our theses and apparently did not think educating women astronomers was pointless![7] Caltech physics provided a few other examples of terminated or continued careers. Lorella M. Jones received a physics MS in 1964, no Caltech Ph.D., and had died by 2005. Melinda Flory, daughter of Nobelist Paul J. Flory (chemistry 1974), received a physics MS in 1965, married Donald H. Groom (Physics Ph.D. 1956), and did not complete a Ph.D. They still had the same address in 2005, and he was part of the Particle Data Group at LBL. Jean Hebb Swank (Ph.D. 1967 physics) used her husband's surname from early on. She was SEK's immediate predecessor in one of those Chicago teaching positions, thought of herself as an astronomer by at least 1976 (AAS member), and was a high energy star of the Goddard Space Flight Center X-ray group until a fairly recent retirement. (VT interjection: she is also one of the nicest and kindest people, and it has ever been my good fortune to know.)

[5]She was the daughter of Georgetown spectroscopist C. C. Kiess, and it is just possible that her choice of graduate discipline was not entirely her own.

[6]A late discovery perhaps bearing on all this is that in 1937 and 1938, Jesse's wife, Naomi Kitay Greenstein, published two sole-author papers in the Bulletin of Harvard College Observatory, concerning light curves of variable stars. She acknowledged data from JLG and an idea from CHPG She had taken a non-technical astronomy course last year at Mount Holyoke from Helen Sawyer Hogg (herself a Mount Holyoke alumna and the 1949 winner of the Annie Jump Cannon award). She told her instructor that she was going to marry an astronomer, and so thought she should learn something about the field. Part of this story comes from George Greenstein, son of Naomi and JLG, and also an astronomer. Thanks here go also to Thomas Burbine and Ronald Zissel of Mount Holyoke for identifying the 1930 faculty there.

[7]Our other doktor grossvaders were Otto Struve (last in a long line of astronomers), Rear Admiral Harry Hammond Hess, Jan Oort (on his day both secretary general and president of the International Astronomical Union), and Donald H. Menzel, whom you met early in the text.

[8]Academic work at Caltech was and is organized into Divisions, two of which are called "Physics, Mathematics, and Astronomy" and "Geological and Planetary Sciences." Within these are "Graduate Options." Some of the options relevant here are Physics, Astronomy (Astrophysics came later), Geology, and Planetary Sciences. Divisions have chairs and option coordinators. Graduate admissions have always been handled by the options. Greenstein was brought to Caltech to build up an astronomy staff to go with the then new Palomar observatory and to build a graduate program. Thus, while he was clearly the head of the astronomy option, he was not actually chairman thereof. Admission letters came from whomever was in charge of an option or his designated representative. Thus, it was J. Beverly Oke who wrote to VT: "…we have reviewed your qualifications and, and on the basis of them, conclude that we cannot deny you admission to the California Institute of Technology; but we think you might be happier elsewhere." JLG resigned as director of the astronomy program/option in 1973. His successors were less outspoken in their views on women astronomers, but it was a good long while after we all finished before the next gal received a Caltech astro degree.

[9]Though each of us individually has at least a private memoir, oral history, or Wiki.

[10]The Henry M. Robinson Laboratory of Astrophysics was built in 1932. In our time, it stretched upward from a third basement (housing male graduate students and the lair of Fritz Zwicky) to faculty offices above ground and to the roof with its one-tenth scale model of the 200″ Hale telescope. The ground floor library's main room had flowered thick carpets, fine old wood tables, walls, bookshelves, and a fabulous mural ceiling. A small room at the back, to the left as you entered, was the office of Alexander Pogo, and the one at the back right had three desks for women graduate students with our names on the door in as many languages as we could

master (thanks AVP for the Armenian, Ed for the Russian, Jim for the Elvish, others for Chinese, Japanese, and multiple languages of India; VT did the Egyptian hieroglyphs). The arrangement was intended to enable librarian Eleanor Ellison to act as dueña, not always successfully. After we had completed our Ph.D. degrees, that back room became a storage area for all the astronomy theses completed over the years, until, in due course, not just the library, but the whole building was "repurposed," and astronomy moved to the south side of California Blvd into the Cahill Center. JGC and AIS have had offices in both buildings.

[11]You are probably too young to remember, but the launch of Sputnik caused widespread American panic, one response to which was munificent government investment in what is now called STEM education and research. At peak, the Apollo program received something like 4.6% of the U.S. Gross National Product. This era ended suddenly in 1972, with the Apollo program being cancelled after launch 17, just as many Ph.D. programs sent forth almost as many astronomy Ph.D. recipients as their departments had promised in the 1964 Whitford report, [National Research Council (NRC), *Ground-based Astronomy: A Ten-Year Program* (National Academy of Sciences, Washington, D.C., 1964)].

[12]Besides the over-representation of seven-sisters among our BAs, another respect in which we would like to resemble the giantesses ranging from Dorrit Hoffleit at about 5′2″ to Cecilia Payne Gaposchkin at 5′10″ on whose shoulders we stand is their longevity! Birth years ranged from 1863 to 1923 and numbers of years lived (ages will be smaller by 1/2 year on average) from 57 to 100 and counting, with median 87 and average 87.1 years. This was in a time frame when the life expectancy for white women in the United States ranged from about 42 to 64 at birth. Remember, of course, that baby girls who died of typhus at 2 never won the Cannon Prize. Our median birth year must be close to 1943, with life expectancy at birth about 70. We are all "above average" in this respect. Check back in around 2030 to see whether we can match our scientific ancesstresses' record.

[13]You know her from outlines of the story of dark matter. Her degrees were from Vassar Astronomy, 1948 (the only one her year), MS from Cornell, 1951, and Ph.D. from Georgetown University in 1954, her research concurrent with the arrival of her first two children. Princeton, fools that they were, had said "no" to admitting her on the grounds of gender.

[14]The Nuclear Astrophysics course of William A. Fowler (Physics Nobel 1983) provided one safe way across that hurdle. It was graded pass-fail, and he said to pass, you just had to come every day, and if you didn't, you had to tell him, because otherwise he wouldn't know. Despite being offered MWF at 8 a.m., it was understandably popular. Starting in about 1966, a year of General Relativity with Kip Thorne (Nobel 2017) was another and much tougher, option. VT audited it. JGC took it for credit and could be heard, during the week of the take-home final, pacing up and down our limited office space saying "I hate you, Kip Thorne. I hate you!" The up side was that if you actually completed one of the problems, it was publishable, and V.T. did her first post-Ph.D. paper with Thorne.

[15]The third way of fulfilling the language requirement was to produce a usable translation of some serious book in one's field that had not previously been translated. VT in the summer of 1965 attempted Otto Heckmann's, *Theorien der Kosmologie* (Springer, Berlin,1942), which would have been, if available in the US and UK by 1946, actually useful. She failed and learned only much later (a) that Heckmann had refereed part I of her Ph.D. thesis for publication (his original territory having been astrometry and stellar dynamics) and (b) that he had been a member of the National Socialist party.

[16]Dorrit Hoffleit, *Misfortunes as Blessings in Disguise* (American Association of Variable Star Observers, Cambridge, 2002).

[17]VT still has her checkbooks and cancelled checks for 1965–1968; financial details are burned into some others' memories.

[18]AVP, JGC, and VT had access to cars. All were graduation presents from parents. For AVP, it was one given to her husband, Bruce, at MIT graduation; JGC's came from her parents at college graduation; VT's was for high school graduation; well, it was Hollywood High.

[19]JLG reported later that he had made sincere effort to read the entire Tolkien trilogy, trying to figure out why we were all so taken by it. He was in his late 50s by then and experienced total failure to understand.

[20]The 3rd or 4th hand lore was that the grapefruit juice and tea formed a ketone or an ester with the alcohol, and so you didn't notice it until the molecules separated again in the presence of stomach acid.

[21]JLG advised unmarried women students not to use a middle initial on their early papers because "we would need that space for the initial of our maiden names when we married." In fact, we are completing our careers with the surnames that are on our Ph.D. diplomas, (three birthnames, four husbands' names) and the extent to which we took his "initial advice" can be judged by checking out our (excessively?) numerous papers on the Astrophysical Data System (http://adswww.harvard.edu/).

[22]Herbert Goldstein, *Classical Mechanics* (Addison-Wesley, Reading, MA, 1951).

[23]Robert B. Leighton, *Principles of Modern Physics* (McGraw-Hill, New York, 1959). While rapidly ceasing to be "modern" even then, the book is still useful if you happen to be interested in the history of physics in the first half of the 20th century.

[24]Robert H. Dicke and J. P. Wittke, *Introduction to Quantum Mechanics*, 1st ed. (Addison-Wesley, Reading, MA, 1960).

[25]John David Jackson, *Classical Electrodynamics*, 1st ed. (John Wiley & Sons, New York, 1962).

[26]The alternative was electricity and magnetism from "Smythe's notes," which a visiting faculty member, Peter A.G. Scherer (radio astronomy), described as "Calculate the potential due to an infinite charged venetian blind." The undergraduate electricity and magnetism book, Panofsky and Phillips (Wolfgang K. H. Panofsky and Melba Phillips, *Classical Electricity and Magnetism* (Addison-Wesley, Reading, MA, 1962), cost $12.75.

[27]This is the same John David Jackson who published a number of items in the American Journal of Physics, during the era of Editor Robert Romer, presumably intended to make physics clearer than it was in a typical textbook other than his!

[28]Books on stellar atmospheres and interiors by Lawrence Aller (then of UCLA) were the listed Caltech texts for a couple of graduate astronomy courses, but the Caltech faculty did not think very highly of them. Indeed, several sometimes lectured from notes they had taken at Chicago with Chandrasekhar. On page 96, the Aller volume on stellar interiors (Lawrence Aller, *Nuclear Transformations, Stellar Interiors, and Nebulae* (Ronald Press, New York, 1954)) mentions that "Mrs. M. H. Harrison has calculated a stellar model whose energy is derived from gravitational contraction and so has energy generation proportional to T, vs $T^{3.5}$ for the proton-proton chain." You met her as one of JLG's semi-drop-outs, and we hope that this is not the reason the Caltech faculty did not admire the book.

[29]This is a quote. Efforts to Google it will lead you unhelpfully into things called Me and Shakespeare. In fact, Ben Johnson wrote, in his *Timber*, or *Discoveries Made Upon Men and Matter*, "I loved the man (Shakespeare) and do honor his memory, on this side idolatry, as much as any."

[30]S. E. Kayser, "Photometry of the nearby irregular galaxy NGC 6822," Astron. J. **72**, 134–148 (1967).

[31]Jesse L. Greenstein and Virginia L. Trimble, "The Einstein red shift in white dwarfs," Astrophys. J. **149** 283–298 (1967).

[32]Virginia Trimble, "Motions and structure of the filamentary envelope of the Crab Nebula," Astron. J. **73**, 535–547 (1968).

[33]During the preparation of these vignettes, SEW decided she did not want to be included. Thus information about her comes entirely from open, public sources accessed on May 17, 2019. The sources include the Astrophysics Data System; Wikimedia; Caltech alumni directory; accolade and response for the Penrose Prize of the Geological Society of American.

[34]H. Zirln and S. Werner Solar Physics **1**, 66 (1967), Detailed analysis of flares, magnetic fields, and activity in the sunspot group of September 13–26, 1962. (This appeared in Vol. 1 of Solar Physics, expressing faith in a brand new journal).

[35]Susan Werner Kieffer, "Shock metamorphism of the Coconino Sandstone at Meteor Crater, Arizona," J. Geophys. Res. **76**(23), 5449–5473, https://doi.org/10.1029/JB076i023p05449 (1971).

[36]Jesse L. Greenstein and Anneila I. Sargent, "The nature of faint blue stars in the Halo II," Astrophys. J. Suppl. **28**, 157–209 (1974).

[37]Anneila I. Sargent, "Molecular clouds and star formation I. Observations of the Cepheus OB3 molecular cloud," Astrophys. J. **218**, 736–748 (1977).

[38]Donna Weistrop, "Equivalent width of Hα in late-type stars," Publ. Astron. Soc. Pacific **79**, 546–550 (1967).

[39]Donna Weistrop, "The luminosity function and density distribution of disk population stars," Astron. J. **77**, 849–862 (1972).

[40]Donna Weistrop, "A new upper limit to the local population II density," Astron. J. **77**, 366–373 (1972).

[41]Judith G. Cohen, Armin J. Deutsch, and Jesse L. Greenstein, "The spectrum of a^2 Canum Venaticorum, 5000–6700 Å," Astrophys. J. **156**, 629–651(1969).

[42]Judith Gamora Cohen, "The lithium isotope ratio in F and G field stars," Astrophys. J. **171**, 71–77 (1972).